Environmental Science and Policy 94 (2019) 262–266

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Short communication

Policies to reduce CO_2 emissions: Fallacies and evidence from the United States and California

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ARTICLE INFO

Keywords:
Cap-and-trade
Carbon emissions trading
Decoupling
Economic growth
USA
California

ABSTRACT

Since the 1990s, advocates of policy to prevent catastrophic climate change have been divided over the appropriate economic instruments to curb CO_2 emissions—carbon taxes or schemes of emission trading. Barack Obama claimed that policies implemented during his presidency set in motion irreversible trends toward a clean-energy economy, with the years 2008–2015 given as evidence of decoupling between CO_2 emissions and economic growth. This is despite California being the only state in the USA that has implemented a specific policy to curb emissions, a cap-and-trade scheme in place since 2013. To assess Obama's claims and the effectiveness of policies to reduce CO_2 emissions, we analyze national and state-level data from the USA over the period 1990–2015. We find: (a) annual changes in emissions strongly correlated with the growth conditions of the economy; (b) no evidence for decoupling; and (c) a trajectory of CO_2 emissions in California which does not at all support the claim that the cap-and-trade system implemented there has reduced CO_2 emissions.

1. Introduction

During his last days in office, President Obama became deeply involved in climate change policy. He pushed for the USA to sign-up to the Paris Agreement and published an article in *Science* where he asserted optimistically that "the trend toward clean energy is irreversible" and, claiming credit for it, he stated that trend had emerged during his presidency (Obama, 2017). For Obama, data showed that reducing CO_2 emissions is compatible with economic growth, because from 2008 to 2015 emissions from the energy sector decreased by 9.5% while the economy grew by more than 10%. This was taken by him to represent a "decoupling" of CO_2 emissions and economic growth, which "should put to rest the argument that combatting climate change requires accepting lower growth or a lower standard of living". Obama did not recommend any specific policy beyond cutting federal fossil-fuel subsidies and continuing with measures that "encourage businesses to save money by cutting energy waste". Technological advances, falling costs of renewable electricity and market forces in general are, in Obama's view, the drivers of a transition leading the USA toward clean energy and leadership in climate change mitigation.

Decoupling has become a major hope of many governments because it offers the possibility of avoiding the major transformation of the economy that is otherwise necessary to remove fossil fuels. In so-called negative emissions scenarios, future technologies are promised that will allow business as usual with CO_2 emissions being captured after fossil fuel combustion. Controversially, the last report of the Intergovernmental Panel on Climate Change (IPCC) made extensive use of such scenarios in its predictions of how to avoid climate change (Anderson, 2015). Decoupling and negative emissions technologies lie behind many governments being prepared to sign-up to the Paris Agreement, which also endorsed the United Nations Sustainable Development Goals (UN SDGs). The UN SDGs include 7% economic growth (Goal 8) and specify (Goal 8.4) that nations should improve resource efficiency and "endeavour to decouple economic growth from environmental degradation" (Anon., 2015).

Unfortunately, there are good reasons to be less optimistic than Obama, the IPCC and the UN SDGs. Recent reports of the International Energy Agency (Anon., 2018) indicate a strong rise in global CO_2 emissions in 2017, a year in which the world economy grew at 3.8%, accelerating its rate of growth from 3.2% in 2016 (Anon., 2019). The historian of energy Vaclav Smil notes a vast inertia in our world's dependence on fossil fuels, which limit a rapid shift to zero-emission energy sources (Voosen, 2018). Infrastructure and modern lifestyles (e.g. cars, flying) have locked-in fossil-fuel dependency for decades to come. The expansion of renewables has not seen a decline in fossil-fuel consumption but rather more overall energy use. As shown by Richard York, over the past half century, in most nations, "each unit of total national energy use from

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https://doi.org/10.1016/j.envsci.2019.01.007
Received 10 August 2018; Received in revised form 24 December 2018; Accepted 17 January 2019
Available online 18 February 2019
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non-fossil-fuel sources displaced less than one-quarter of a unit of fossil-fuel energy use;" furthermore, "each unit of electricity generated by non-fossil-fuel sources displaced less than one-tenth of a unit of fossil-fuel-generated electricity" (York, 2012). The available fossil fuel reserves exceed by six times or more what can be burnt to stand a 66% chance of preventing a 2 °C temperature rise (Spash, 2016). Yet, development of non-conventional sources (e.g. tar sands, oil shale, fracking) is on-going, thus increasing the fossil-fuel reserves that can be burnt only by causing catastrophic warming (Raupach, 2014).

What is to be done? Disagreements amongst those wanting policies to cut CO_2 emissions are common. Nine years ago, a high-profile exchange occurred between climate scientist James Hansen (Anon., 2009) and economist Paul Krugman (Krugman, 2009). Krugman proposed a system of capping emissions, distributing emissions permits and setting a market for trading them, what is called a cap-and-trade policy. While accepting that policy as imperfect and insufficient, Krugman argued this was at least politically feasible and could be made increasingly effective over time. Hansen disagreed and advocated a carbon fee, or tax, with full reimbursement, which Krugman regarded as politically unviable. Hansen viewed cap-and-trade as allowing polluters and Wall Street traders "to fleece the public out of billions of dollars" (Hansen, 2009), while doing nothing to cut emissions. Despite support from some prominent conservative economists (Baker et al., 2017), the Hansen proposal has not been implemented anywhere. In contrast, emissions trading, which always had many sources of support in the USA (Lohmann, 2006), has proven politically acceptable with, for example, such schemes established in 2005 in the European Union and, in 2013, in California.

Despite the apparent success, and going beyond Hansen's criticisms, the carbon trading system has also been shown to be potentially harmful both socially and environmentally (Spash, 2010). Its practical application in Europe has had generally poor evaluations in terms of effectiveness for reducing emissions (Verschuuren and Fleurke, 2015), but we will not deal with the European experience in this paper. Instead we use data from the USA to show the link between economic activity and CO_2 emissions and to assess both decoupling and emissions trading. We provide empirical evidence to evaluate Obama's claim that decoupling CO_2 emissions from economic growth is not only feasible but already occurring. We also analyze emissions data in order to evaluate the cap-and trade system implemented in California.

2. Emissions and the economy

Data on energy-related annual emissions of CO_2 up to 2015 are available from the US Energy Information Administration (Energy Information Administration, U.S. Department of Energy, 2018). Over the period 2000–2015, CO_2 energy-related emissions fell in 41 states and rose in 9 states. The greatest percentage decrease was in Maine (25%) and the greatest rise in Nebraska (22%). As shown in Fig. 1, the evolution of CO_2 emissions in specific states and in the nation at large is one of overall emissions decline. By 2015, national emissions and emissions of many states were lower than in the early years of the century.

National and state emissions in the USA generally declined during the recession of 2001 and the Great Recession of 2007–2009. The accepted chronology of the National Bureau of Economic Research shows the economy was in recession between March and November 2001 and between December 2007 and June 2009. Thus 2001, 2008 and 2009 can be considered recession years, as the national economy was in recession at least during part of each of those years.

Data on state CO_2 emissions during the period 2000–2015 can be classified by the 13 years of expansion and 3 years of recession. There are then 663 state-year cases of economic expansion (51 states, including DC as a state, for 13 years) and 153 cases of recession (51 states for 3 years). State emissions barely increased in the expansion years, as their mean change was 0.3%, with a standard deviation of 4.5%, but they substantially decreased in the recession years, when on average, they decreased by 3.6%, with a standard deviation of 5.1%. Obviously, these figures reveal large variability implied by standard deviations greater than the means. Much stronger evidence of the link between the economy and the level of emissions is given for instance by the correlation between the energy-related CO_2 emissions and the nominal GDP of the 50 states (as reported by the US Bureau of Economic Analysis). For any year between 2001 and 2015 this correlation is between 0.76 and 0.81, which implies a high level of statistical significance ($n = 50$, $P < 0.0001$) indicating that the volume of state emissions is very strongly correlated with the size of the state economy. Also, evidence that changes in emissions depend on changes in the economy can be obtained by modeling the relative change in annual emissions of each state ($[E_t - E_{t-1}] / E_{t-1} = \Delta E_t / E_{t-1}$) as a function of the change in economic conditions, indexed by the change in the annual unemployment rate of the state ($\Delta U = U_t - U_{t-1}$).[1] Such a regression model was computed with 800 observations (16 years times 50 states) yielding the following results (standard errors below the parameter estimates):

$$\Delta E_t/E_{t-1} = \underset{(0.16)}{-0.30} - \underset{(0.15)}{1.06}\,\Delta U_t \qquad R^2 = 0.06, \quad \text{Durbin Watson } d = 2.3$$

which indicates that, on average, one percentage point increase in the state unemployment rate is associated with a decrease of emissions by 1.06%. With a standard error of 0.15, this estimate is highly statistically significant ($P < 0.001$).

Table 1 shows the results of this regression for each of the 50 states of the USA. The estimate of the effect of the change in unemployment on the change in emissions is statistically significant only in a few cases, which is not surprising given the small sample size, but the estimate is negative in 45 out of the 50 states, which is clearly suggestive of the decline in emissions being dependent on recession conditions. Indeed, in Tennessee and Texas, the two states where the dependence appear more intense, the change in economic conditions indexed by the change in unemployment explains almost 40% of the change in emissions. For California, the R^2 of the regression is 0.19, which means that annual changes in economic conditions in the period 2000–2015 explain 19% of the variation in energy-related emissions. In that state, in the 13 years in which the economy was in expansion, emissions increased on average 0.5% per year (with a standard deviation of 2.6%), while in the 3 years of recession, they decreased on average 2.2% (with a standard deviation of 3.0%). Thus, both the state-level data for the whole nation and the experience of California provide significant evidence, confirming previous findings (Tapia Granados et al., 2012; Tapia Granados and Carpintero, 2013), that emissions evolve in close connection with the performance of the economy.

3. Decoupling

Obama argued that between 2008 and 2015 the economy grew "by more than 10%", while emissions from the energy sector dropped by 9.5%. In his view this was supporting evidence for the hypothesis that economic growth and CO_2 emissions in the USA are decoupling or have already decoupled (Obama, 2017). Fig. 2 allows us to examine directly the evolution of both variables between 2008 and 2015. In that period "the economy," that is, Gross Domestic Product (GDP), was indeed increasing, while emissions were decreasing. The most recently available data show that in 2015 emissions were 9.2% below the 2008 level, while GDP, measured in chained 2009 dollars, was 11.1% above the 2008 level. This is consistent with Obama's numerical statement.

However, a basic rule in statistics is that correlating trends usually leads to false inferences and spurious conclusions (Bisgaard and Kulahci, 2011). Fig. 3 also shows national CO_2 emissions and GDP, but both variables are now plotted as rates of growth. Long-term increases or decreases are gone, both curves oscillate without any clear trend. Yet

[1] An accepted regularity in economics is Okun's law, which states that the correlation of GDP growth with the change in unemployment is strong and negative. Therefore, the change in unemployment can be used as a proxy for economic growth.

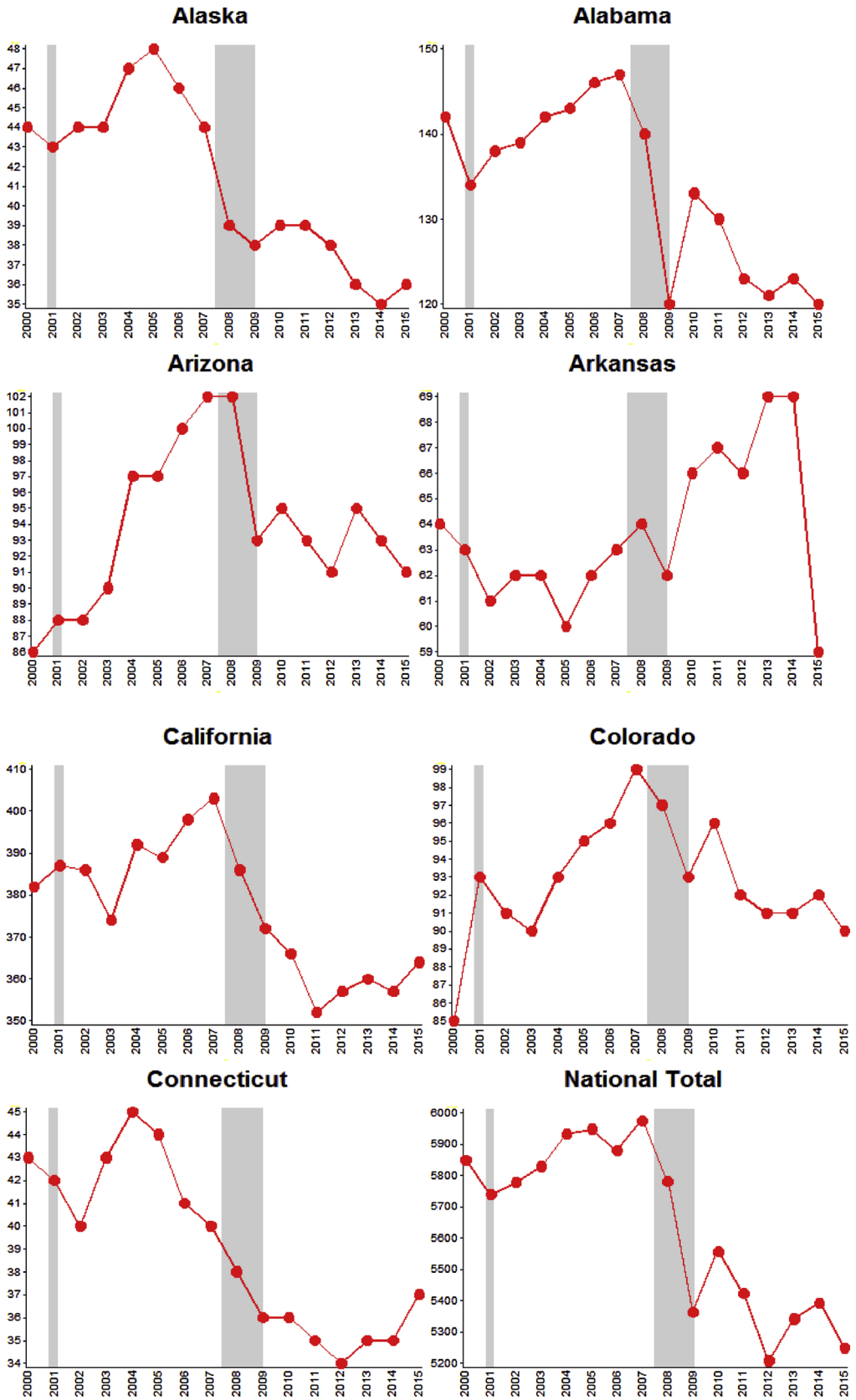

Fig. 1. CO_2 energy-related emissions in the USA and seven states. Shaded areas correspond to the 2001 recession and the Great Recession of 2008–2009; emissions are millions of metric tonnes.

Table 1
Effect of a one percentage point increase in the year-to-year change of the state unemployment rate on the annual percentage increase in emissions in each of the 50 states of the USA (standard errors in parenthesis).

State	Estimate	R^2	State	Estimate	R^2
Tennessee	−5.64 (1.89)**	0.39	Oklahoma	−0.65 (0.59)	0.08
Texas	−1.72 (0.59)*	0.38	Alaska	−0.70 (0.68)	0.07
New Jersey	−3.98 (1.38)*	0.37	Indiana	−0.88 (0.87)	0.07
Idaho	−2.84 (1.23)*	0.28	New Hampshire	−1.08 (1.10)	0.06
Alabama	−2.42 (1.10)*	0.26	Montana	−1.15 (1.19)	0.06
Pennsylvania	−1.30 (0.60)*	0.25	Minnesota	−0.51 (0.58)	0.05
Virginia	−3.91 (1.80)*	0.25	Wyoming	−0.54 (0.63)	0.05
Utah	−1.75 (0.91)†	0.21	South Carolina	−0.77 (0.92)	0.05
Delaware	−3.71 (2.02)†	0.19	Mississippi	−1.42 (1.80)	0.04
California	−1.50 (0.83)†	0.19	Colorado	−0.50 (0.67)	0.04
Florida	−1.60 (0.91)†	0.18	Hawaii	−1.02 (1.39)	0.04
Wisconsin	−1.91 (1.09)	0.18	Ohio	−2.19 (3.39)	0.03
West Virginia	−2.43 (1.47)	0.16	Maine	0.86 (1.35)	0.03
N. Dakota	−0.76 (0.46)	0.16	Kentucky	−0.70 (1.21)	0.02
N. Carolina	−2.01 (1.26)	0.15	Georgia	−0.40 (0.99)	0.01
Louisiana	−1.73 (1.13)	0.14	Iowa	−0.26 (0.73)	0.01
Connecticut	−1.32 (0.89)	0.14	Rhode Island	−0.44 (1.25)	0.01
Illinois	−1.10 (0.74)	0.13	Arkansas	−0.16 (0.94)	0.00
Washington	−1.79 (1.27)	0.12	Nevada	0.67 (4.10)	0.00
Arizona	−2.96 (2.13)	0.12	Missouri	0.14 (0.90)	0.00
Massachusetts	−2.03 (1.51)	0.11	Kansas	0.30 (2.08)	0.00
Michigan	−1.07 (0.80)	0.11	New Mexico	−0.09 (0.81)	0.00
New York	−1.53 (1.17)	0.11	South Dakota	−0.09 (0.91)	0.00
Nebraska	1.26 (1.07)	0.09	Maryland	−0.09 (1.12)	0.00
Vermont	−1.50 (1.33)	0.08	Oregon	−0.01 (1.33)	0.00

** $P < 0.01$, ** $P < 0.05$, † $P < 0.1$. Estimates are based in regressions including data for the years 2000-2015, so that each regression was computed with 16 observations.

the annual rates of growth of emissions and GDP are highly correlated, both tend to be high, medium or low in the same years, and this is true both before and after 2008. The correlation between the two variables, as shown in Table 2, is highly significant over the 25-year period, but during the period 2008–2015 the correlation is 0.67, stronger than the correlation during the earlier period 1990–2007, 0.58. The strength of the correlation between the rates of growth of GDP and CO_2 emissions both in recent decades and in the recent period 2008–2015 selected by Obama are inconsistent with the claim of decoupling. Since 1990, emissions in the USA, as in other countries, have stagnated or expanded during periods of economic expansion, while they have declined during economic recessions. This provides evidence against decoupling, rather than in favor of it.

4. Effectiveness of the California cap-and-trade scheme

The California Global Warming Solutions Act, Assembly Bill 32 (AB32), was passed in 2006, establishing specific targets for reductions in CO_2 emissions. One of the policies triggered by the law was the Californian Cap-and-Trade Program. Since January 1, 2013, this has set enforceable compliance obligations for emissions of greenhouse gasses and a system for trading of emission allowances.

An initial assessment of the effectiveness of this cap-and-trade scheme can be made by comparing the evolution of Californian CO_2 emissions with those of the other states of the Union, taken as a control group. Fig. 1 shows how emissions in California and the nation evolved before and after 2013, the year in which the cap-and-trade system started to be enforced. The graph does not at all suggest that the California cap-and-trade program is effective, because Californian emissions increased between 2013 and 2015, while they decreased in the nation at large.

To be more precise, we can make a before-after comparison, examining how emissions evolved before and after 2013 in California and in the other states of the nation. There is no objective way to decide the exact years to use for the before and after comparison; for instance, we could compare the mean annual change of emissions in 2013–2015 with say, the mean annual change in 2010–2012, or 2000–2010, there are multiple options. Comparing, for instance, two 3-year periods before and after reveals that California had mean annual CO_2 emissions of 358.3 megatons in 2010–2012 and 360.3 megatons in 2013–2015, which represents an increase of 0.6%. In a ranking of all states this places California in 36th position, among the extremes of Georgia, where emissions decreased the most, 1.6%, and North Dakota, where they increased 6.8%. Data for mean annual emissions over a longer 5-year reference period, 2008–2012, show that California reduced emissions by 1.7%, which places it in 34th position in the rank of states; Georgia remains in 1st place with 14.3% reduction in emissions, and North Dakota in 51st place, with 8.4% increase in emissions. These comparisons show that since the cap-and-trade system has been in place in California, most states have actually had larger reductions in emissions than California. While the period in which the system has been in place is short, these preliminary estimates do not provide any evidence that the emissions trading system has effectively led to any reduction in Californian CO_2 emissions.

5. Conclusion

Greenhouse gases are well known to be related to fossil fuels upon which the industrial modern economy is dependent. Yet the idea has been

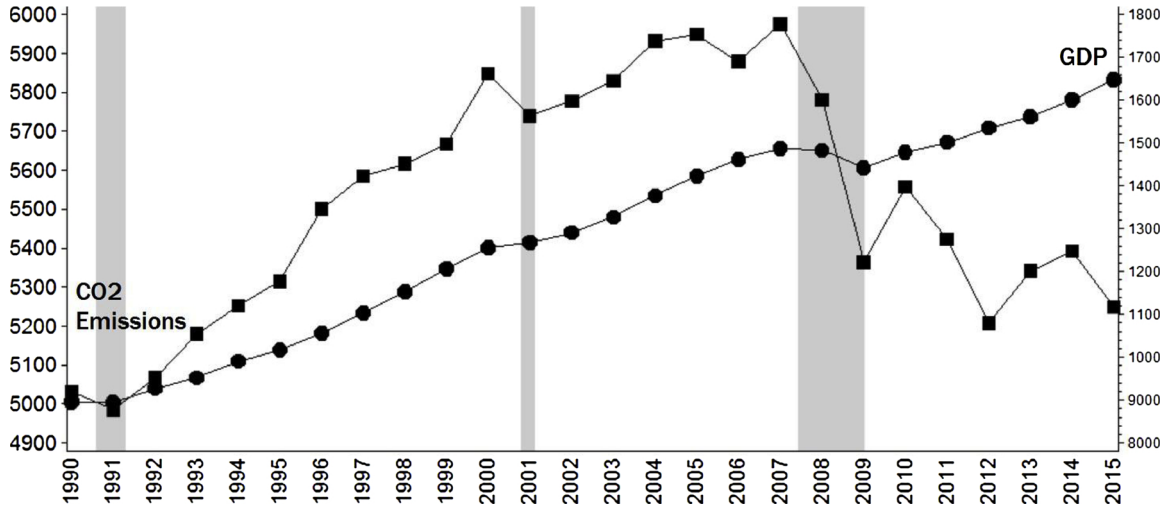

Fig. 2. GDP and CO_2 emissions, USA, 1990–2015. GDP in billions of chained dollars of 2009, from the Bureau of Economic Analysis; energy-related CO_2 emissions in million metric tons, from the US Energy Information Agency; shaded areas correspond to recessions.

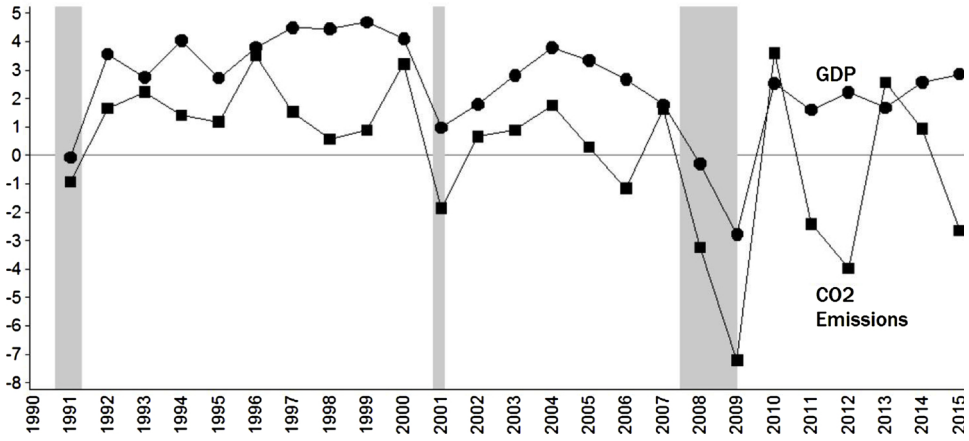

Fig. 3. Annual percentage rate of growth in GDP and CO_2 emissions, USA 1990-2015. Author's computations from data in Fig. 2; shaded areas correspond to recessions.

Table 2
Correlations between the annual rates of growth of GDP and energy-related CO_2 emissions, USA 1991–2015.

Sample	Sample size	Correlation	*P*-value
1991–2015	25	0.70	< 0.0001
2008–2015	8	0.67	0.07
1991–2007	17	0.58	0.01

Reported correlations are Pearson correlation coefficients.

put forward that current economic systems can be decoupled from their material and energy throughput. We have provided evidence that CO_2 emissions in the USA are significantly correlated with economic growth. Contrary to the claims made by former President Obama, the only evidence for decoupling of these two variables in the USA is a faulty use of statistics.

If the introduction of low carbon energy sources is having any impact on emissions there is no reason to expect this to be large because these energy sources supply a very small part of energy consumed in the USA. As Feng et al. have shown, any decline in national CO_2 emissions in the USA over recent years appears largely connected with the relative stagnation of the economy following the Great Recession of 2008–2009 (Feng et al., 2015). This, combined with long-term processes of deindustrialization, that go back to the 1980s, explain emissions reductions

In addition, the claim that emission trading is an effective policy instrument for the reduction of carbon emissions is not supported by the available evidence. We have shown that the cap-and-trade system in California has had no apparent effect on the trajectory of emissions in that state compared with that of other states. On this basis, the advocacy of cap-and-trade systems for reduction of emissions lacks any supporting empirical evidence.

6. Author Contributions

J.A.T.G. analyzed the data and wrote the first draft, which was expanded and changed with the contributions of C.L.S. Both authors approved the final version.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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